

**WHAT IS CLAIMED IS:**

1. A photomask comprising:

a mask pattern formed on a transparent substrate; and

a transparent portion of said transparent substrate where said mask pattern is not

5 formed,

wherein said mask pattern includes a main pattern to be transferred through exposure and an auxiliary pattern that diffracts exposing light and is not transferred through the exposure,

said main pattern is composed of a first semi-shielding portion that has first  
10 transmittance for partially transmitting said exposing light and transmits said exposing light in an identical phase with respect to said transparent portion, and a phase shifter that transmits said exposing light in an opposite phase with respect to said transparent portion, and

said auxiliary pattern is made from a second semi-shielding portion that has  
15 second transmittance for partially transmitting said exposing light and transmits said exposing light in the identical phase with respect to said transparent portion.

2. The photomask of Claim 1,

wherein said first transmittance is 15% or less.

3. The photomask of Claim 1,

20 wherein said second transmittance is not less than 6% and not more than 50%.

4. A photomask comprising:

a mask pattern formed on a transparent substrate; and

a transparent portion of said transparent substrate where said mask pattern is not  
formed,

25 wherein said mask pattern includes a main pattern to be transferred through

exposure and an auxiliary pattern that diffracts exposing light and is not transferred through the exposure,

a part of said transparent portion is disposed between said main pattern and said auxiliary pattern, and

5 with respect to an oblique incident angle  $\phi_A$  defined as  $\sin\phi_A = NA \times SA$  when a given oblique incident position is indicated by SA (wherein  $0.4 \leq SA \leq 0.8$ ), a center of said auxiliary pattern is disposed in or in the vicinity of a position away from a center of said main pattern by a distance  $M \times (\lambda / (2 \times \sin\phi_A))$ , wherein  $\lambda$  indicates a wavelength of said exposing light and M and NA indicate magnification and numerical aperture of a  
10 reduction projection optical system of an aligner.

5. The photomask of Claim 4,

wherein said main pattern is made from a shielding portion or a phase shifter that transmits said exposing light in an opposite phase with respect to said transparent portion.

6. The photomask of Claim 4,

15 wherein said main pattern is composed of a semi-shielding portion that has transmittance for partially transmitting said exposing light and transmits said exposing light in an identical phase with respect to said transparent portion, and a phase shifter that transmits said exposing light in an opposite phase with respect to said transparent portion.

7. The photomask of Claim 6,

20 wherein said phase shifter is disposed at a center of said main pattern to be surrounded by said semi-shielding portion.

8. The photomask of Claim 7,

wherein a dimension of a part of said semi-shielding portion sandwiched between said phase shifter and said transparent portion is not less than 20 nm and not more than  $(0.3 \times \lambda / NA) \times M$ , wherein  $\lambda$  indicates a wavelength of said exposing light and M and NA  
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indicate magnification and numerical aperture of a reduction projection optical system of an aligner.

9. The photomask of Claim 7,

wherein a dimension of a part of said semi-shielding portion sandwiched between said phase shifter and said transparent portion is not less than  $1/4$  of a wavelength of said exposing light and not more than  $(0.3 \times \lambda/NA) \times M$ , wherein  $\lambda$  indicates the wavelength of said exposing light and M and NA indicate magnification and numerical aperture of a reduction projection optical system of an aligner.

10. The photomask of Claim 7,

wherein said main pattern is composed of a shielding portion replaced with said semi-shielding portion and said phase shifter.

11. The photomask of Claim 6,

wherein said phase shifter is disposed in a peripheral portion of said main pattern to be surrounded by a part of said semi-shielding portion.

12. The photomask of Claim 6,

wherein said semi-shielding portion has transmittance of 15% or less.

13. The photomask of Claim 4,

wherein said auxiliary pattern is made from a shielding portion or a semi-shielding portion that has transmittance for partially transmitting said exposing light and transmits said exposing light in an identical phase with respect to said transparent portion.

14. The photomask of Claim 13,

wherein the transmittance of said semi-shielding portion is not less than 6% and not more than 50%.

15. A photomask comprising:

a mask pattern formed on a transparent substrate; and

a transparent portion of said transparent substrate where said mask pattern is not formed,

wherein said mask pattern includes a main pattern to be transferred through exposure and an auxiliary pattern that diffracts exposing light and is not transferred through the exposure,

a part of said transparent portion is disposed between said main pattern and said auxiliary pattern, and

with respect to an oblique incident angle  $\phi_B$  defined as  $\sin\phi_B = NA \times SB$  when a given oblique incident position is indicated by SB ( $0.4 \leq SB \leq 0.8$ ), a center of said auxiliary pattern is disposed in or in the vicinity of a position away from a center of said main pattern by a distance  $M \times ((\lambda/(2 \times \sin\phi_B)) + (\lambda/(NA + \sin\phi_B)))$ , wherein  $\lambda$  indicates a wavelength of said exposing light and M and NA indicate magnification and numerical aperture of a reduction projection optical system of an aligner.

16. The photomask of Claim 15,

wherein said main pattern is made from a shielding portion or a phase shifter that transmits said exposing light in an opposite phase with respect to said transparent portion.

17. The photomask of Claim 15,

wherein said main pattern is composed of a semi-shielding portion that has transmittance for partially transmitting said exposing light and transmits said exposing light in an identical phase with respect to said transparent portion, and a phase shifter that transmits said exposing light in an opposite phase with respect to said transparent portion.

18. The photomask of Claim 17,

wherein said phase shifter is disposed at a center of said main pattern to be surrounded by said semi-shielding portion.

19. The photomask of Claim 18,

wherein a dimension of a part of said semi-shielding portion sandwiched between said phase shifter and said transparent portion is not less than 20 nm and not more than  $(0.3 \times \lambda/NA) \times M$ , wherein  $\lambda$  indicates a wavelength of said exposing light and M and NA indicate magnification and numerical aperture of a reduction projection optical system of an aligner.

20. The photomask of Claim 18,

wherein a dimension of a part of said semi-shielding portion sandwiched between said phase shifter and said transparent portion is not less than 1/4 of a wavelength of said exposing light and not more than  $(0.3 \times \lambda/NA) \times M$ , wherein  $\lambda$  indicates the wavelength of said exposing light and M and NA indicate magnification and numerical aperture of a reduction projection optical system of an aligner.

21. The photomask of Claim 18,

wherein said main pattern is composed of a shielding portion replaced with said semi-shielding portion and said phase shifter.

22. The photomask of Claim 17,

wherein said phase shifter is disposed in a peripheral portion of said main pattern to be surrounded by a part of said semi-shielding portion.

23. The photomask of Claim 17,

wherein said semi-shielding portion has transmittance of 15% or less.

24. The photomask of Claim 15,

wherein said auxiliary pattern is made from a shielding portion or a semi-shielding portion that has transmittance for partially transmitting said exposing light and transmits said exposing light in an identical phase with respect to said transparent portion.

25. The photomask of Claim 24,

wherein the transmittance of said semi-shielding portion is not less than 6% and

not more than 50%.

26. A photomask comprising:

a mask pattern formed on a transparent substrate; and

a transparent portion of said transparent substrate where said mask pattern is not

5 formed,

wherein said mask pattern includes a main pattern to be transferred through exposure and an auxiliary pattern that diffracts exposing light and is not transferred through the exposure,

said auxiliary pattern includes a first auxiliary pattern that is disposed in or in the  
10 vicinity of a position away from a center of said main pattern by a distance X with a part of said transparent portion sandwiched between said main pattern and said first auxiliary pattern, and a second auxiliary pattern that is disposed on a side of said first auxiliary pattern farther from said main pattern in or in the vicinity of a position away from a center of said first auxiliary pattern by a distance Y with a part of said transparent portion  
15 sandwiched between said first auxiliary pattern and said second auxiliary pattern, and

said distance X is larger than said distance Y.

27. The photomask of Claim 26,

wherein when a given oblique incident position is indicated by S (wherein  $0.4 \leq S \leq 0.8$ ), a relationship,  $X/Y = (1 + S)/(2 \times S)$ , holds.

20 28. The photomask of Claim 26,

wherein when a given oblique incident position is indicated by SA (wherein  $0.4 \leq SA \leq 0.8$ ), with respect to an oblique incident angle  $\phi_A$  defined as  $\sin \phi_A = NA \times SA$ , a relationship,  $X = M \times (\lambda / (2 \times \sin \phi_A))$ , holds.

29. The photomask of Claim 26,

25 wherein said main pattern is made from a shielding portion or a phase shifter that

transmits said exposing light in an opposite phase with respect to said transparent portion.

30. The photomask of Claim 26,

wherein said main pattern is composed of a semi-shielding portion that has transmittance for partially transmitting said exposing light and transmits said exposing light in an identical phase with respect to said transparent portion, and a phase shifter that transmits said exposing light in an opposite phase with respect to said transparent portion.

31. The photomask of Claim 30,

wherein said phase shifter is disposed at a center of said main pattern to be surrounded by said semi-shielding portion.

32. The photomask of Claim 31,

wherein a dimension of a part of said semi-shielding portion sandwiched between said phase shifter and said transparent portion is not less than 20 nm and not more than  $(0.3 \times \lambda/NA) \times M$ , wherein  $\lambda$  indicates a wavelength of said exposing light and M and NA indicate magnification and numerical aperture of a reduction projection optical system of an aligner.

33. The photomask of Claim 31,

wherein a dimension of a part of said semi-shielding portion sandwiched between said phase shifter and said transparent portion is not less than 1/4 of a wavelength of said exposing light and not more than  $(0.3 \times \lambda/NA) \times M$ , wherein  $\lambda$  indicates the wavelength of said exposing light and M and NA indicate magnification and numerical aperture of a reduction projection optical system of an aligner.

34. The photomask of Claim 31,

wherein said main pattern is composed of a shielding portion replaced with said semi-shielding portion and said phase shifter.

35. The photomask of Claim 30,

wherein said phase shifter is disposed in a peripheral portion of said main pattern to be surrounded by a part of said semi-shielding portion.

36. The photomask of Claim 30,

wherein said semi-shielding portion has transmittance of 15% or less.

5 37. The photomask of Claim 26,

wherein said first auxiliary pattern and said second auxiliary pattern are made from a shielding portion or a semi-shielding portion that has transmittance for partially transmitting said exposing light and transmits said exposing light in an identical phase with respect to said transparent portion.

10 38. The photomask of Claim 37,

wherein the transmittance of said semi-shielding portion is not less than 6% and not more than 50%.

39. A photomask comprising:

a mask pattern formed on a transparent substrate; and

15 a transparent portion of said transparent substrate where said mask pattern is not formed,

wherein said mask pattern includes a main pattern to be transferred through exposure and an auxiliary pattern that diffracts exposing light and is not transferred through the exposure,

20 said auxiliary pattern includes a first auxiliary pattern that has a width D1 and is disposed with a part of said transparent portion sandwiched between said main pattern and said first auxiliary pattern and a second auxiliary pattern that has a width D2 and is disposed on a side of said first auxiliary pattern farther from said main pattern with a part of said transparent portion sandwiched between said first auxiliary pattern and said second  
25 auxiliary pattern, and



said width D2 is larger than said width D1.

40. The photomask of Claim 39,

wherein a ratio  $D2/D1$  is not less than 1.2 and not more than 2.

41. The photomask of Claim 39,

5 wherein said main pattern is made from a shielding portion or a phase shifter that transmits said exposing light in an opposite phase with respect to said transparent portion.

42. The photomask of Claim 39,

wherein said main pattern is composed of a semi-shielding portion that has transmittance for partially transmitting said exposing light and transmits said exposing  
10 light in an identical phase with respect to said transparent portion, and a phase shifter that transmits said exposing light in an opposite phase with respect to said transparent portion.

43. The photomask of Claim 42,

wherein said phase shifter is disposed at a center of said main pattern to be surrounded by said semi-shielding portion.

15 44. The photomask of Claim 43,

wherein a dimension of a part of said semi-shielding portion sandwiched between said phase shifter and said transparent portion is not less than 20 nm and not more than  $(0.3 \times \lambda/NA) \times M$ , wherein  $\lambda$  indicates a wavelength of said exposing light and M and NA indicate magnification and numerical aperture of a reduction projection optical system of  
20 an aligner.

45. The photomask of Claim 43,

wherein a dimension of a part of said semi-shielding portion sandwiched between said phase shifter and said transparent portion is not less than 1/4 of a wavelength of said exposing light and not more than  $(0.3 \times \lambda/NA) \times M$ , wherein  $\lambda$  indicates the wavelength of  
25 said exposing light and M and NA indicate magnification and numerical aperture of a

reduction projection optical system of an aligner.

46. The photomask of Claim 43,

wherein said main pattern is composed of a shielding portion replaced with said semi-shielding portion and said phase shifter.

5 47. The photomask of Claim 42,

wherein said phase shifter is disposed in a peripheral portion of said main pattern to be surrounded by a part of said semi-shielding portion.

48. The photomask of Claim 42,

wherein said semi-shielding portion has transmittance of 15% or less.

10 49. The photomask of Claim 39,

wherein said first auxiliary pattern and said second auxiliary pattern are made from a shielding portion or a semi-shielding portion that has transmittance for partially transmitting said exposing light and transmits said exposing light in an identical phase with respect to said transparent portion.

15 50. The photomask of Claim 49,

wherein the transmittance of said semi-shielding portion is not less than 6% and not more than 50%.

51. A pattern formation method using the photomask of Claim 1, comprising the steps of:

20 forming a resist film on a substrate;

irradiating said resist film with said exposing light through said photomask; and

forming a resist pattern by developing said resist film having been irradiated with said exposing light.

52. The pattern formation method of Claim 51,

25 wherein an oblique incident illumination method is employed in the step of

irradiating said resist film.

53. A pattern formation method using the photomask of Claim 4, comprising the steps of:

forming a resist film on a substrate;

5 irradiating, through said photomask, said resist film with said exposing light emitted by annular illumination; and

forming a resist pattern by developing said resist film having been irradiated with said exposing light.

54. The pattern formation method of Claim 53,

10 wherein an average of an outer diameter and an inner diameter of a lighting shape used in said annular illumination is not less than 0.58 and not more than 0.8, whereas values of said outer diameter and said inner diameter are standardized by numerical aperture of an aligner.

55. A pattern formation method using the photomask of Claim 4, comprising the steps of:

forming a resist film on a substrate;

irradiating, through said photomask, said resist film with said exposing light emitted by quadrupole illumination; and

20 forming a resist pattern by developing said resist film having been irradiated with said exposing light.

56. The pattern formation method of Claim 55,

25 wherein a distance from a light source center to a center of each of four polarized lighting shapes used in said quadrupole illumination is not less than  $0.4/(0.5)^{0.5}$  and not more than  $0.6/(0.5)^{0.5}$ , whereas a value of said distance is standardized by using numerical aperture of an aligner.

57. A mask data creation method for creating mask data for a photomask including a mask pattern formed on a transparent substrate and a transparent portion of said transparent substrate where said mask pattern is not formed, comprising the steps of:

generating a main pattern corresponding to a desired unexposed region of a resist  
5 formed by irradiating said resist with exposing light through said photomask;

determining a shape of a phase shifter that is disposed within said main pattern and transmits said exposing light in an opposite phase with respect to said transparent portion;

disposing an auxiliary pattern for diffracting said exposing light in a position on  
10 said transparent substrate away from said phase shifter by a given distance;

setting an edge of said main pattern corresponding to a boundary between said main pattern and said transparent portion as a CD adjustment edge;

predicting, through simulation, a dimension of a resist pattern formed by using said main pattern including said phase shifter and said auxiliary pattern; and

15 changing a shape of said main pattern by moving said CD adjustment edge when said predicted dimension of said resist pattern does not accord with a desired dimension.

58. The mask data creation method of Claim 57,

wherein said main pattern includes a semi-shielding portion that transmits said exposing light in an identical phase with respect to said transparent portion.

20 59. The mask data creation method of Claim 58,

wherein said phase shifter is disposed at a center of a part having a given or smaller dimension of said main pattern to be surrounded by said semi-shielding portion.

60. The mask data creation method of Claim 59,

25 wherein said phase shifter is disposed with a part of said semi-shielding portion having a given or larger width sandwiched between said transparent portion and said phase

shifter.

61. The mask data creation method of Claim 58,  
wherein said phase shifter is disposed in a peripheral portion of said main pattern.

62. The mask data creation method of Claim 57,

5 wherein said main pattern includes a shielding portion, and  
said phase shifter is disposed at a center of a part having a given or smaller  
dimension of said main pattern to be surrounded by said shielding portion.

63. The mask data creation method of Claim 62,

10 wherein said phase shifter is disposed with a part of said shielding portion having  
a given or larger width sandwiched between said transparent portion and said phase shifter.

64. A mask data creation method for creating mask data for a photomask  
including a mask pattern formed on a transparent substrate and a transparent portion of said  
transparent substrate where said mask pattern is not formed, comprising the steps of:

15 generating a main pattern corresponding to a desired unexposed region of a resist  
formed by irradiating said resist with exposing light through said photomask;

separating said main pattern into a first region and a second region;

disposing a first auxiliary pattern for diffracting said exposing light in a position  
on said transparent substrate away from said first region of said main pattern by a given  
distance; and

20 disposing a second auxiliary pattern for diffracting said exposing light in a  
position on said transparent substrate away from said second region of said main pattern by  
another given distance.

65. The mask data creation method of Claim 64,

wherein either of said first region and said second region is a transistor region.

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